Dual task performance in older adults: examining visual discrimination whilst treadmill walking at preferred and non-preferred speeds

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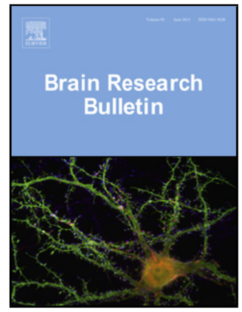

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Dual task performance in older adults: Examining visual discrimination performance whilst treadmill walking at preferred and non-preferred speeds.

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Highlights

- We examined visual-cognitive performance in a sample of older adults before, during and post treadmill walking.
- Walking was completed at preferred walking speed and preferred walking speed + 20%.

- Visual-cognitive performance was facilitated when walking at preferred but not faster than preferred speed.

Abstract

This study examined visual discrimination performance in a sample of older adults before, during and post treadmill walking at preferred walking speed and preferred walking speed + 20%. Nine adults (6 females and 3 males) aged 60-77 years (mean age = 67.1 ± 5.7 years) undertook three trials each lasting 15 minutes, rest, walking at preferred speed and walking at preferred speed + 20%. Pre, during and post each condition participants undertook measures of visual-cognitive performance. There were no significant main effects or higher order interactions for condition (rest, vs walking preferred speed, vs. walking preferred speed +20%) or time (pre, during, post) (all P>0.05). There was a significant condition X time interaction for response time (P = 0.014, partial η^2 =0.352). Post hoc analysis indicated that response times were significantly faster during exercise at preferred speed compared to pre exercise at preferred speed (P = .042). Response times were significantly slower during walking at preferred speed +20% compared to pre exercise (P = .002) and to post exercise (P =.012). Response times were significantly faster during PSW compared to during rest (P = .05), during PSW compared to during PSW20 (P = .001) and significantly slower during PSW20 compared to during rest (P = 0.001). Post PSW20 response times were significantly slower than post PSW (P = .04). These results suggest that visual discrimination performance is facilitated when walking at preferred speeds but walking at 20% faster than preferred speed significantly impedes visual discrimination in older adults.

Keywords: Cognitive Performance; Exercise; Ageing; Dual-Task Processing

Introduction

In daily life it is common that secondary tasks, involving cognitive, perceptual or motor control, are performed at the same time as a primary task such as walking [1]. Understanding such dual-task demands is of particular interest to gerontologists who suggest age related decline in sensorimotor processes increase task interference [2] and results in postural prioritization [3], due to reallocation of limited attentional resource. While most prior work has supported this 'posture first' hypothesis, the pattern of dual task responses is not consistent [4] and research has shown improved verbal fluency performance during walking compared to seated rest in children [5]. The lack of consistency in dual task responses between studies may be due to a number of reasons including differences in secondary task type, e.g., verbal vs. visual and differences in exercise and exercise intensities used. More recently, Tomporowski and Audiffren [4] asked young and older adults to perform an auditory switch test after 5 minutes standing, walking at preferred speed and walking at preferred speed + 50%. They reported that, in both walking conditions, older adults significantly reduced response times, suggesting support for Sanders' arousal theory [6]. Their research identifies an interesting dual-task response for older adults and Tomporowski and Audiffren [4] suggested additional research, employing different cognitive tasks was needed to better understand if different dual-task outcomes occur for non-auditory tests of cognitive performance. Dual task effects of walking on visual performance may be particularly important to examine in older adults as when a visual secondary task is added to walking, the need to manage two streams of visual information concurrently (one related to walking, the other to the secondary task) may exceed the capability of an ageing prefrontal cortex amplifying dual task costs in this age group [1]. Moreover, during/after exercise somatosensory and/or motor information linked to movement persists and generates somatosensory and visual conflicts [7] resulting in different responses to walking depending on the type of cognitive test employed. The choice of a 5minute walking duration and a walking speed at 50% greater than preferred speed was also not clear in the Tomporowski and Audiffren [4] study. Prior meta-regression analysis has identified a time frame of 15minutes before any effect of exercise on cognition is seen [8] and given the findings of Tomporowski and Audiffren [4] it would be of practical interest to examine if any changes in cognitive performance are seen at speeds faster than preferred walking speed but smaller than the preferred speed + 50% used in their study. As walking slightly faster than preferred walking speed may be more likely in day to day situations than walking 50% faster than preferred speed, examining whether dual task performance differs at speeds faster than preferred speed but slower than preferred speed + 50% may offer additional insight into dual task responses when walking. We modified the +50% preferred walking speed model from Tomporowski and Audiffren [4] and instead used an arbitrary ~20% of this speed as an interim benchmark. Therefore, this study sought to examine visual discrimination performance in a sample of older adults before, during and post treadmill walking at preferred walking speed and preferred walking speed + 20%.

Methods

Participants

Nine adults (6 females and 3 males) aged 60-77 years (mean age = 67.1 ± 5.7 years, mean body mass index = 24.3 ± 1.8 kg/m^2) took part in this repeated measures experiment following institutional ethics approval and informed consent. Participants were recruited from a local community group in Coventry, UK. All participants were habitually physically active (>150min per week). Participants were excluded if they had any cardiovascular condition, were taking medications such as beta blockers or calcium ion channel blockers or if there was any other contraindication to exercise. None of the participants reported falling in the previous 12 months, nor did they have any visual impairment. Each participant received a £10 gift voucher as a gratuity for the time taken to participate in the multiple sessions involved in the study.

Procedures

The study used a repeated-measures design whereby participants undertook 4 visits to the laboratory. During the first visit to the laboratory participants learned to walk on a treadmill at different speeds, were familiarised with the computerised cognitive test and as a measure of aerobic endurance performed the 6-minute walk test [9]. In the subsequent 3 sessions, participants performed the visual cognitive performance test prior to, at 13 minutes during (lasting 2 minutes) and 2 minutes post a 15 minute period of either: seated rest, walking at preferred speed and walking at preferred speed + 20%. Experimental conditions were counterbalanced.

Walking Speeds

The preferred speed of walking (PSW) was determined using procedures previously employed by Tomporowski and Audiffren [4]. In brief, participants were instructed to walk on a treadmill set with a 2% gradient. The speed of the treadmill was progressively increased from 1.5kph to 7kph in increments of 0.5kph every 30 seconds. Participants were asked to select which speed they perceived to be their preferred walking speed but were not provided with feedback relating to the actual speed. To verify the preferred speed, each participant then rested for 5minutes before walking on the treadmill at their chosen preferred speed. Participants were then asked to confirm that their preferred speed was at a pace they could comfortably walk at for 15 minutes. Once the participants' PSW was established a faster walking pace was determined (preferred walking speed + 20%, PSW20). In no instances did the walking speeds determined (either preferred speed or preferred speed +20%) result in participants running and all participants completed the 15 minute walking bout. Mean ± SD of walking speeds was 4.5 ± 1.1kph and 5.4 ± 1.2kph for PSW and PSW20.

Visual Discrimination Performance

To assess visual discrimination performance, participants completed a test of visual discrimination modelled on one developed by Pontifex et al [10] and previously used by Moore et al [11]. The test required participants to respond quickly and accurately to a 5.5 cm diameter circle that occurred on 12.5% of trials and not to respond to a 5.0 cm diameter non-target circle that occurred on 75% of trials, or a 2 cm distractor square that occurred on 12.5% of trials. The test consisted of 100 trials and required approximately two minutes to complete. Within the test, stimuli were presented for 300 ms with a 1000 ms inter-stimulus interval via open source experiment software [12] at the centre of a computer monitor located on the treadmill in front of the participant at a distance of 75-80cm away from the participant. For each trial, participants were asked to press a hand held trigger button, with their dominant hand, if the target stimulus was presented which enabled participants to complete the visual discrimination test during exercise. Visual discrimination test performance was calculated as recommended from signal detection theory [13] and comprised of two measures. Participants perceptual sensitivity (P(Ā)) on the visual discrimination test was calculated. P(Ā) reflects a combination of each participant's average percent target detection (hits) and errors of commission (false alarms) and was calculated as per Moore et al [11]. Response times (ms) were also calculated for target stimulus trials indicating the time taken to respond when the target stimulus was presented. Performance on the visual discrimination test was considered as the primary performance variable in the present study.

Heart Rate and Rating of Perceived Exertion

Heart rate (bpm) was monitored continuously (Polar RS400, Polar Electro Oy, Kempele, Finland) and was recorded at 5, 10 and 15minutes of each experimental trial. The Borg [14] 6-20 rating of perceived exertion (RPE) scale was also used as a measure of exercise exertion during experimental trials with ratings also being taken at 5, 10 and 15 (at the very end of the walking trial, once the cognitive task had been completed) minutes of each trial.

Statistical Analysis

Any differences in P(Ā) scores and response times (secs) were analysed using a series of 3 (condition; rest vs. PSW vs. PSW20) X 3 (time; pre, during, post) ways repeated measures analysis of covariance (ANCOVA). Any differences in heart rate were examined using a 3 (condition; rest vs. PSW vs. PSW20) X 3 (time; 5, 10, 15 min during) ways repeated measures ANCOVA and any differences in RPE were examined using a 2 (condition; PSW vs. PSW20) X 3 (time; 5, 10, 15 min during) ways repeated measures ANCOVA. In all cases aerobic fitness was used as a covariate. This approach was employed, in line with prior assertions [8] and practice [4], where lack of control for physical fitness has been purported as one reason for inconsistency in the extant literature on this topic. Analysis was also rerun adjusting for the fact that data were collected at 3 time points (i.e., a time-varying covariate). This did not change the results of the statistical analysis and thus is not presented further. Where any significant differences were evident Bonferroni post-hoc multiple comparisons were used to determine where the difference lay. The statistical package for social sciences (SPSS, version 22) was used for all analysis. P level was set at 0.05 a priori and partial η^2 was used as a measure of effect size.

Results

For response time there was a significant condition X time interaction ($F_{4,28}$ = 3.8, P = 0.014, partial η^2 =0.352, See Figure 1.). Post hoc analysis indicated that response times were significantly faster during exercise at PSW compared to pre exercise at PSW (P = .042). In the PSW20 condition, these times were significantly slower during exercise compared to pre exercise (P = .002) and to post exercise (P =.012). Across conditions, there was significantly faster response times during exercise at PSW compared to during rest (P = .05), during exercise at PSW compared to during PSW20 (P = .001). These were significantly slower during exercise at PSW20 compared to during rest (P = 0.001). Post exercise response times at PSW20 were significantly slower than post exercise at PSW (P = .04). There were no other significant differences across combinations of time and conditions (all P<0.05). For P(Ā), there were no significant main effects or higher order interactions for condition or time (all P>0.05). Mean ± SD of detections (hits) and errors of commission (false alarms) of participants' pre, during and post in rest PSW and PSW conditions are presented in Table 1. In regard to overall target accuracy, participants evidenced a high level of visual discrimination between targets with response accuracy being over 90% in all trials, indicating that sustained attention was directed towards the visual discrimination tests across the experimental protocol.

For heart rate there was a significant main effect for condition ($F_{2,14}$ = 4.7, P = 0.027, partial η^2 =0.403), with heart rate during rest being significantly lower to during exercise at PSW and exercise at PSW20 and exercise at PSW being significantly lower than exercise at PSW20 (all P = .0001). Mean ± SE of heart rate was 70.5 ± 2.9bpm for rest, 90.7 ± 2.4bpm for PSW, and 106.1 ± 2.2bpm for PSW20.

In regard to RPE, significant main effect for time ($F_{2,16}$ = 10.2, P = 0.001, partial η^2 =0.562) and condition ($F_{1,8}$ = 40.1, P = 0.001, partial η^2 =0.834), but not their interaction (P<0.05) indicated that RPE values increased from 5 to 10 minutes during exercise (P = .05) and from 10 minutes during exercise to 15 minutes during exercise (P = .05) and that RPE valued during the PSW condition were significantly lower compared to the PSW20 conditions (P = 0.001). Mean ± SE of RPE was 10.8 ± .21, 11.1 ± .28 and 11.5 ± .20 at 5, 10 and 15 minutes during exercise respectively and 10.3 ± .29 and 12.0 ± .25 for PSW and PSW20 conditions respectively.

All data were also re analysed removing the covariate of physical fitness. This did not change the findings of the analysis in respect to whether or not a significant difference was found but did change the magnitude of the P values found for each dependant variable.

Discussion

The results of this short communication are novel in that they show differential response time responses to a visual-cognitive task during walking at preferred speed and at PSW20. Results for walking at preferred speed, followed an inverted-U shape relationship, whereby response times were improved during exercise compared to pre and post exercise which supports assertions by prior authors that exercise induced arousal at a moderate intensity enhances cognitive and motor performance [15]. Furthermore, the results also support the resource explanation posited by Schaefer et al [5]. It is important to note that, congruent with Tomporowski and Audiffren [4], participant level of fitness did not influence their dual-task performance. However, contrary to Tomporowski and Audiffren's [4] findings for response times, when participants were asked to walk at 20% greater than their preferred walking speed, response times were significantly greater during exercise. The results of the present study, in relation to walking at preferred speed, partially align with Sanders' [6] cognitive energetic model where changes in physiological arousal as a consequence of locomotion lead to faster responses. The discrepancy between the present study and the findings of Tomporowski and Audiffren [4] may be due to the use of a visual cognitive task in the present study compared to an auditory task in the work by Tomporowski and Audiffren

[4]. The auditory task-switching task employed by Tomporowski and Audiffren [4] is a measure of executive function whereas the visual discrimination task employed in the present study is psycho-physical in nature requiring sustained visual attention. Completion of such tasks requires sustained attention to overcome somatosensory/visual conflicts that occur during locomotion [7]. Thus, the effect of exercise walking speed on cognition may be task dependant. Similarly, the findings presented here may be a consequence of the longer duration of walking employed in the present study, necessitating a more sustained period of attentional resource being directed to posture resulting in greater, low level fatigue before commencing the visual-cognitive task. In turn this may result in slower response times when walking at a speed faster than their preferred walking speed. In this respect the results presented here also align with Schaefer et al's [5] resource allocation model, demonstrated in children, in dual task walking. As, in the present study, there was no significant change in visual discrimination accuracy but an increase in response times when asked to walk at 20% faster than preferred speed, these results do align with prior assertions made by Tomporowski and Audiffren [4] that speed-accuracy trade-offs result when walking and undertaking a secondary task. Here, where sustained attention was directed towards a visual discrimination task, response times were slower in order to maintain accuracy, when also undertaking PSW20. This suggests that locomotion, at greater than preferred speeds, under dual-task conditions degrades the quality of older adults' psycho-physical performance.

The difference between PSW and PSW20 was however fairly small (approx. 1kph) and the results presented in response times between conditions might be due to other mechanisms than increased arousal. Walking at greater velocity requires more attention [16] and likely elicits greater conflict between somatosensory information (detecting that the body is moving forwards) and visual afferents (detecting no change in body position). At the same time, faster walking may disturb vestibular control of balance during the primary task due to greater sensitivity of otholitic receptors to linear accelerations whilst walking [17]. Collectively, this may have resulted in a greater reliance on visual information during walking and subsequently less residual visual resources available during PSW20 compared to PSW. Given the task employed in the present study was psycho-physical in nature the distance between the monitor and the position of the participant on the treadmill would play a substantial role on target discrimination. We employed a visual discrimination test which had been used in prior research [10,11] and in an orientation where pilot data suggested participants could accurately discriminate between the different stimuli. It is thus likely that greater attentional resources would be required to complete this task, particularly during PSW20 and compared to other types of cognitive task.

We acknowledge that the results of this study are based on a small sample of, habitually active, older adults and further research is warranted to verify the trends presented here. The age range of the participants is also fairly large. It may be interesting to examine whether responses differ in older adults of different activity status (e.g., sedentary vs. active) and whether responses differ between younger-old adults and older-old adults. The reach of this study in explaining dual task walking performance is also restricted as no walking parameters were assessed during experimental trials. As a consequence, although postural prioritisation may be inferred as a mechanism for poorer cognitive performance during PSW20 conditions, the current study cannot evidence this. Assessment of gait parameters in future studies would therefore be worthwhile. Despite this, the results presented here are novel and suggest that visual discrimination response times are reduced when walking at preferred speeds but walking at 20% faster than preferred speed significantly impedes visual cognitive performance in older adults.

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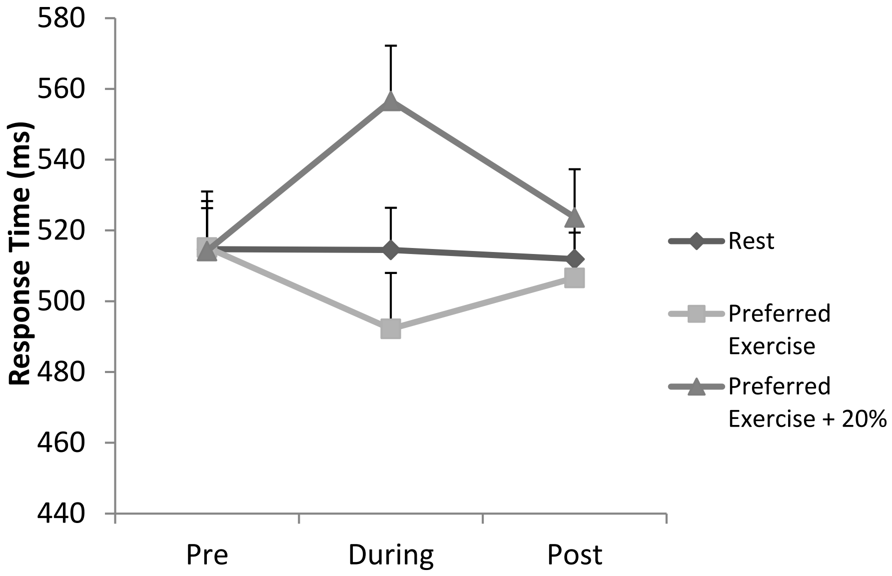

Figure 1. Mean ± SE of response times (ms) pre, during and post 15 minutes rest, exercise at preferred walking speed and exercise at preferred walking speed + 20%

Table 1. Mean ± SD of detections (hits) and errors of commission (false alarms) of participants pre, during and post in rest, preferred walking speed (PSW) and preferred walking speed + 20% (PSW) conditions.

	Pre				During				Post			
	Hits		False Alarms		Hits		False Alarms		Hits		False Alarms	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Rest	74.1	0.8	0.9	0.5	74.2	0.8	2.5	0.4	74.0	0.9	1.5	0.8
PSW	73.2	1.5	1.4	0.8	72.6	2.2	1.9	0.8	73.8	1.1	1.1	0.8
PSW20	74.0	0.8	1.3	0.5	67.9	2.8	1.4	1.3	73.4	1.1	0.8	0.5